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MEASURING SYSTEM ~~AND METHOD FOR~~ ~~THE~~ FUNCTIONAL MONITORING THEREOF

The present invention is directed to a measuring system, in particular to a position-measuring system, whose functioning is simple to test, as set forth in Claim 1. The present invention is also directed to a method for testing for correct functioning, as set forth in Claim 4.

In position-measuring systems, position sensors in a measuring device generate electrical signals, which provide information on the position of objects which are moving in relation to one another. The present invention relates, in particular, to measuring systems that use measuring devices which produce comparatively precise, incremental positional information, as well as relatively rough positional information. These two types of positional data are of particular importance for controlling the electric drives used in moving the axes of a processing machine, such as of a machine tool or robot. In such applications, the precise, incremental, positional information is used to precisely determine positions, for example of a tool of a machine tool.

Often, such electric drives are designed as rotary electromotors, for which rotary transducers are typically used to perform angle-of-rotation measurements. However, the present invention may also be used in connection with the operation of linear motors.

Rotary transducers are known which enable angular position measurements to be taken on a rotatable shaft in incremental measuring steps. However, so-called absolute-value encoders, also described as rotary encoders, are also known. These permit an absolute angular determination to be made within one single shaft rotation. Moreover, if the need arises to

determine the number of completed shaft rotations, then so-called multiturn rotary encoders are typically used. Such multiturn rotary encoders determine the absolute angular position within one shaft rotation, i.e., between 0° and 360°, using an encoder disk which is connected to the shaft and is scanned by a suitable photoelectric scanning unit. Thus, it is also possible to measure the absolute position of the driven shaft over a plurality of rotations.

The signals of these measuring devices are often used for controlling the processing machines. The term processing machine is not limited to machine tools, but also includes machines for populating electronic components or for machining semiconductor elements. Automation machines, such as robots, also fall under the processing-machine designation.

In conventional position-measuring systems under the state of the art, in addition to the digital positional data, analog position signals are also transmitted from the measuring device to the machine control, where these signals are then interpolated. Due to the advancing miniaturization of electronics, these interpolation processes are now being increasingly carried out in a suitable electronic circuit within the measuring device itself, so that the analog position signals are not transmitted to the machine control. This reduces the outlay for wiring, which has a significant effect on the costs of a measuring system.

However, in safety-related machine applications under known methods heretofore, the digital positional data and the analog position signals are compared in the machine control in order to detect errors. However, since analog position signals are now missing in the machine control, it is no longer possible for this comparison to be made.

Therefore, in measuring systems, in which no analog position signals arrive in the machine control for the mentioned reasons, besides the current, often absolute positional data, it is not unusual for so-called static bits to be transmitted via a parallel or serial interface from the measuring device to the machine control. These static bits can be error bits, for example, which, in normal operation, always exhibit a specific level, and only in a (very rare) case of error, point to an error due to a change in level.

It turns out, however, that especially in the case of safety-related monitoring, this way of transmitting error information is disadvantageous, because it cannot be ruled out that a defect will cause a constant level of an error bit to continually be output, thus that this defect does not permit a change in level even in the case of faults.

The German Patent 38 29 815 C2 of the applicant describes a position-measuring device, where a test for errors is initiated by an activation signal. However, the performance reliability of the monitoring electronics itself cannot be checked by the invention it describes. Moreover, the outlay entailed for signal transmission is comparatively large.

The object of the present invention is, therefore, to devise a measuring system which will render possible a safe and reliable operation of processing machines, the outlay for signal transmission being comparatively low.

This objective is achieved in accordance with the present invention by the features of Claim 1.

Moreover, a method for checking error information is devised by the present invention, which will significantly enhance the

safety and reliability of processing machines. This is achieved by the method as set forth in Claim 4.

The idea underlying the present invention is that a fault is able to be induced, in a deliberate, controlled manner, in the measuring device during a test operation, and it is then checked by applying a test potential, whether an error bit having a corresponding level arrives in the machine control. It is intended, in particular, for the present invention to enable the performance reliability of a monitoring electronics, e.g., of a signal-amplitude monitoring circuit to be checked. The test potential may be understood, for instance, to be the voltage of a test potential source or, in the simplest case, the earth potential.

In one preferred embodiment of the present invention, the circuit states for connecting to the test potential source, in particular automatically, are triggered by the machine control.

Advantageous embodiments of the present invention may be inferred from the dependent claims.

Further advantages of the measuring system according to the present invention and of the corresponding method, as well as details pertaining thereto, are derived from the following description of an exemplary embodiment, on the basis of the enclosed figures, which show:

Figure 1a a schematic representation of one embodiment of the measuring system according to the present invention in normal operation;

Figure 1b a schematic representation of one embodiment of the measuring system according to the present invention in test operation;

Figure 2 a voltage curve when the test voltage is used;

Figure 3 a schematic representation of another embodiment of the measuring system according to the present invention.

In Figure 1a, a measuring system is shown, which includes a rotary transducer 1, a machine control 2, and a data-transmission means 3.

Rotary transducer 1 has photoelements 1.1, 1.2, amplifiers 1.3, 1.4, an evaluation electronics 1.5, and a signal-amplitude monitoring circuit 1.6. Situated at the lines between amplifiers 1.3, 1.4 and evaluation electronics 1.5, are branch lines having resistors 1.7, 1.8. Disposed above that in the circuit of rotary transducer 1 are control elements 1.9, 1.10, which electrically contact a test potential source 1.11.

Control elements 1.9, 1.10 may assume two control element states. In the first control element state, test potential source 1.11 is isolated from signal-amplitude monitoring circuit 1.6; in the second control element state, an electrical contact is established between test potential source 1.11 and signal-amplitude monitoring circuit 1.6.

Data-transmission means 3 is made up of an interface socket 3.1 at rotary transducer 1, a multicore cable 3.3 having plug connectors, and an interface socket 3.1 at machine control 2. Alternatively thereto, a wireless data-transmission means 3 may also be provided. Correspondingly, suitable transmitter and receiver elements may be provided in place of interface sockets 3.1, 3.2.

In accordance with the angular position of a shaft to be measured, light from an LED that is not shown in the figures, is modulated and converted by photoelements 1.1, 1.2 into photoelectric currents. These photoelectric currents are amplified with the aid of amplifiers 1.3, 1.4, so that the result is analog position signals, which have a sinusoidal form, as in accordance with Figure 2. These position signals are fed in evaluation electronics 1.5, inter alia, to an interpolation process, thereby enabling the angular or positional resolution of measuring device 1 to be greatly increased. Moreover, in evaluation electronics 1.5, absolute digital positional values are generated, which, in the illustrated example, are transferred as a data packet, composed of a multiplicity of data bits, serially via interfaces 3.1, 3.2 and cable 3.3 to the machine control in a cycle time of 50 μs.

In parallel thereto, the analog position signals are fed to a signal-amplitude monitoring circuit 1.6. It is checked in this signal-amplitude monitoring circuit 1.6 whether the amplitudes of the analog position signals are within plausible limits. In normal operation, this criterion is met by the analog position signals, so that the same data packet used to transmit the absolute digital positional values to machine control 2 is also used to transmit an error bit, whose level signals the normal state, i.e., the fault-free operation of the measuring system. Thus, this error bit is typically transmitted at a constant level, in the exemplary embodiment presented here, every 50 μs, from measuring device 1 to machine control 2 and is, therefore, described as a static error bit.

As soon as the amplitudes of the analog position signals are outside of the plausible limits, the level of the error bit is changed, and the corresponding error bit is transmitted to

machine control 2 via the next data packet. In reaction thereto, machine control 2 triggers an emergency shutoff for the entire machine.

The situation can also arise, however, where the level of the error bit is not able to be changed, for example, due to a short circuit. Then, in spite of a fault, the same error bit level is relayed to machine control 2, with the result that the machine would not be shut down, even in response to a fault.

To avoid such a danger, a test operation is carried out for a short duration using a control element state, as shown in accordance with Figure 1b. For this purpose, a signal is dispatched by machine control 2 to the measuring device. The signal is transmitted in the form of a code word, or mode command, by machine control 2 via a data line of cable 3.3 to rotary transducer 1. The data line of cable 3.3 is used both for transmitting the mode commands from machine control 2 to rotary transducer 1, as well as for transmitting data and signals, including the error bit, from rotary transducer 1 to machine control 2. Thus, as made clear by the double arrow in Figures 1a, 1b, and 3, it is a question of a bidirectional data transmission between machine control 2 and rotary transducer 1.

The transmitted mode command is decoded in rotary transducer 1, so that the test operation is triggered, which initially results in closing of control elements 1.9, 1.10. Thus, voltage U_0 of test-potential source 1.11 is now supplied to signal-amplitude monitoring circuit 1.6. The level of voltage U_0 is derived from the voltage curve of the corresponding analog position signal (corresponds to the axis of symmetry of the voltage curve of the analog position signal) in accordance with Figure 2. As shown in Figure 1b, resistors 1.7, 1.8

substantially prevent voltage U_0 from being induced in evaluation electronics 1.5. Thus, given a closed control element 1.9, signal-amplitude monitoring circuit 1.6 ascertains that the amplitude of the analog position signal is insufficient and, therefore, outputs an error bit having a changed level. Machine control 2 is programmed in such a way that, during three cycle times, thus, in this case 150 µs, following injection of voltage U_0, no reaction (emergency off) is triggered in response to the receipt of an error bit having a changed level.

However, should no level change in the error bit be ascertained by machine control 2, although voltage U_0 had been injected, then an error message indicating the same is output. In this manner, it is possible, in particular, to test signal-amplitude monitoring circuit 1.6 for correct functioning.

In another embodiment of the present invention, in accordance with Figure 3, a digital signal-amplitude monitoring circuit 1.12 is additionally integrated in evaluation electronics 1.5. It carries out a plausibility control of the digitized positional data in parallel to signal-amplitude monitoring circuit 1.6. In normal operation, an emergency-off is triggered, as soon as an error bit having a changed level arrives in machine control 2, regardless of whether it comes from signal-amplitude monitoring circuit 1.6 or from digital signal-amplitude monitoring circuit 1.12. Of course, an emergency-off also follows when both signal-amplitude monitoring circuits 1.6, as well as digital signal-amplitude monitoring circuit 1.12 signal an error via an error bit having a changed level.

If at this point in test operation, signal-amplitude monitoring circuit 1.6 is tested for correct functioning by applying test potential U_0, then machine control 2 may be

programmed not to trigger an emergency-off in response to the receipt of an error bit having a changed level from signal-amplitude monitoring circuit 1.6. However, if error bits having a changed level, thus quasi two error messages, from both signal-amplitude monitoring circuit 1.6 and from digital signal-amplitude monitoring circuit 1.12, reach machine control 2 in test operation, then an emergency-off is triggered. In this way, a sufficient level of reliability may be provided in test operation as well.

The present invention is not limited to measuring systems and methods for monitoring position signals generated by photoelements 1.1, 1.2. Rather, the present invention also makes it possible to consider, inter alia, temperature signals, frequency-describing signals, or signals which provide information about the charge condition of batteries.

In particular, the present invention may advantageously be used for position-measuring devices, which, besides positional data, transmit additional measuring data from other sensors via a shared interface or via the shared data-transmission means 3, bidirectionally between the position-measuring device, in this case rotary transducer 1 and machine control 2. Thus, for example, in addition to positional measurements in rotary transducer 1, speed and/or velocity measurements are also often taken using a Ferraris sensor, for instance. The performance reliability of the signal monitoring of these sensors may also be tested using the present invention. The same also applies to rotary transducer 1, in which a temperature-monitoring circuit, for instance for an electromotor, is integrated. The performance reliability of the temperature-signal monitoring may also be advantageously tested using the present invention.